# Sub-seasonal variability of the Asian summer monsoon transport of CO and aerosols to the UTLS and implications for global atmospheric composition


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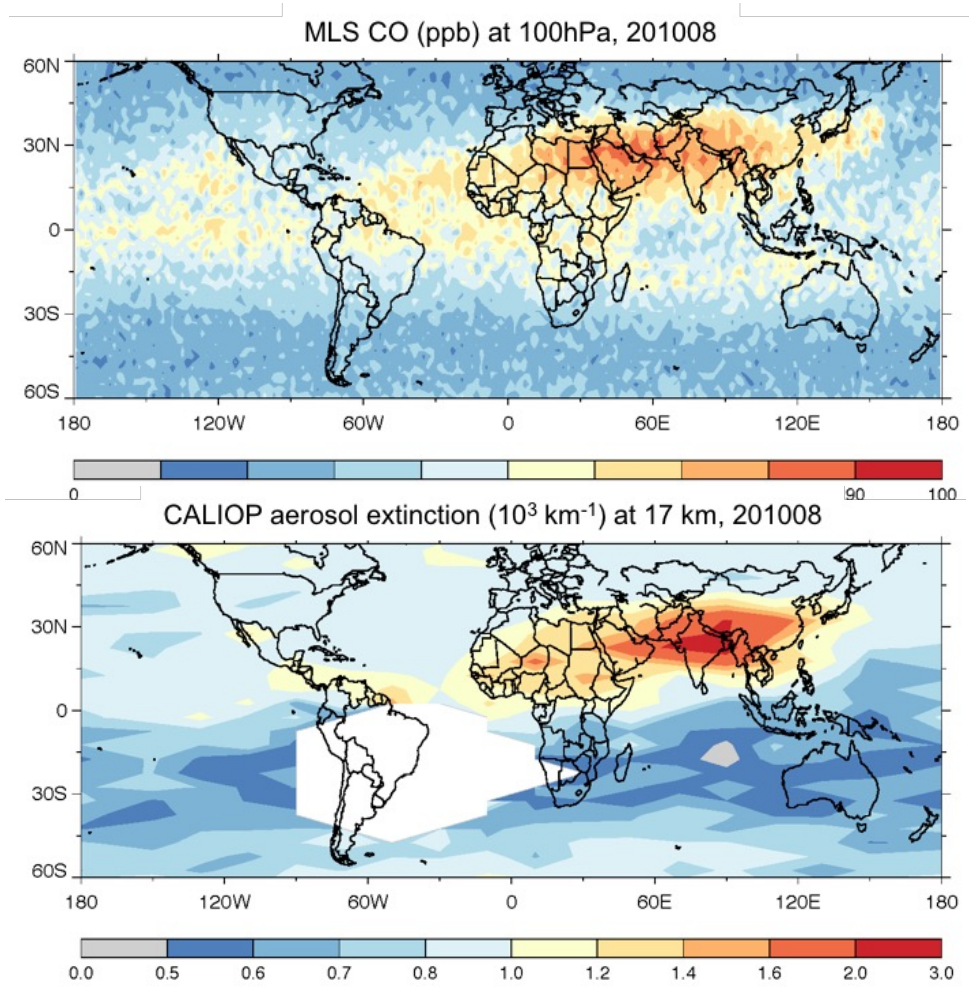


# Introduction

- The upper troposphere/ lower stratosphere (UTLS) is a climate sensitive region
- The Asian summer monsoon (ASM) is a major component in the climate system. It transports aerosols and trace gases from the most polluted regions in Asia to UTLS where they spread out to the global atmosphere

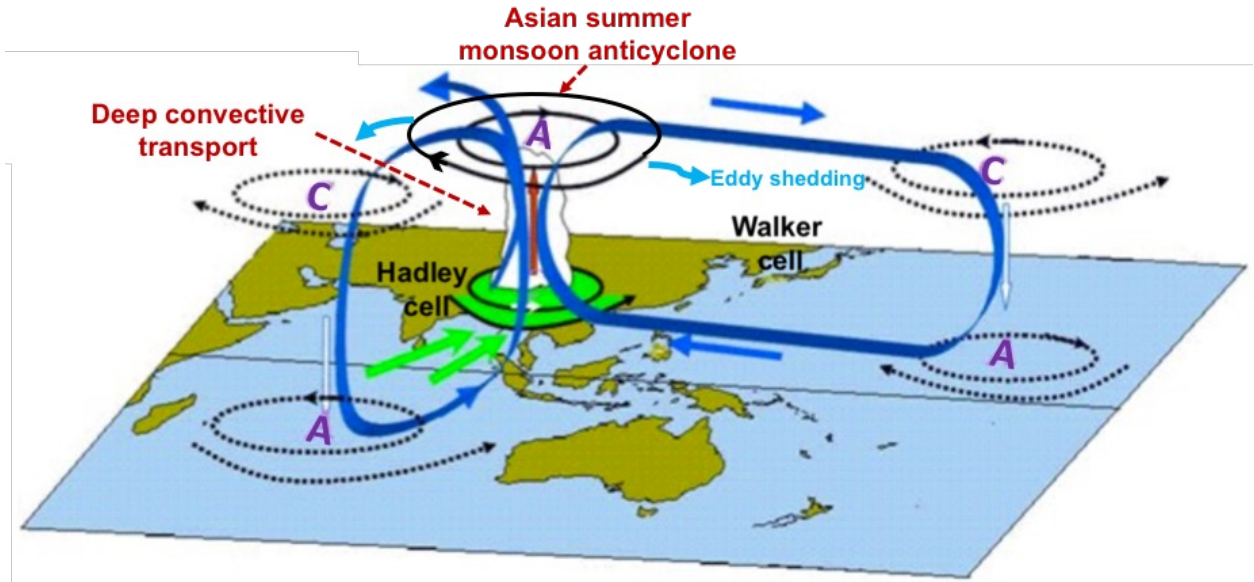


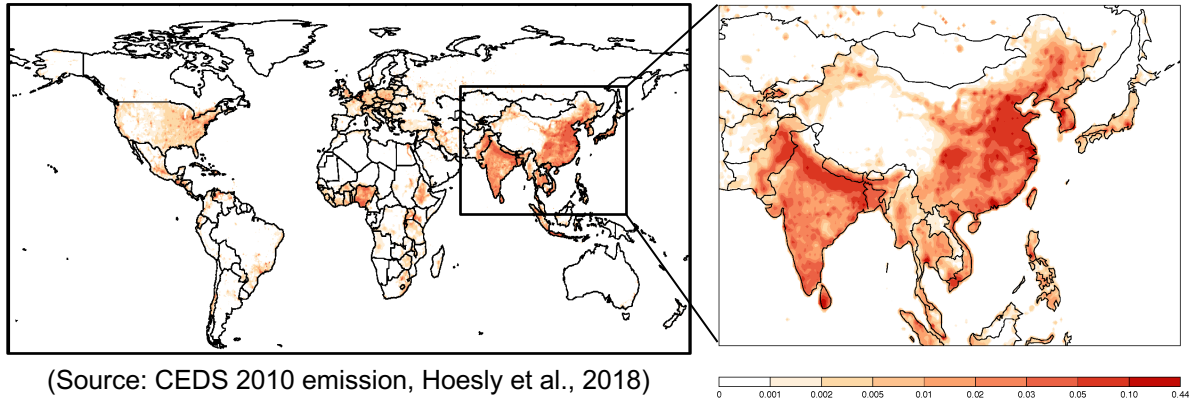

Figure from: https://www.clivar.org/asian-australian-monsoon

- Although ASM is a seasonal phenomenon with strongest global influences usually seen in summer, it is highly dynamic and connected to other weather and climate systems, with significant spatial and temporal variability ranging from sub-seasonal weather scale to multi-year climate scale. The interplay of multi-scale dynamics inevitably determines the variability of the transport pathways and atmospheric composition in the UTLS

# Study objective and method

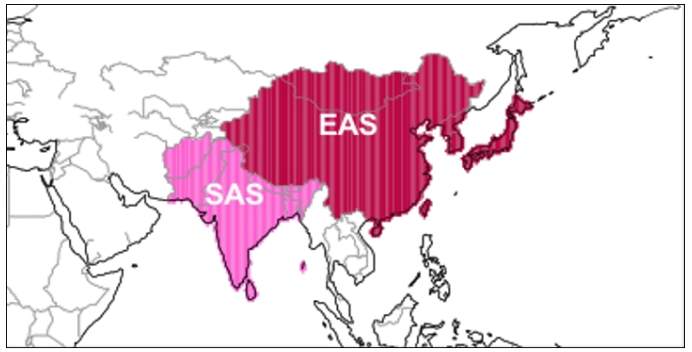
- The study presented here focuses on examining the sub-seasonal variability of CO and aerosols in the UTLS over the ASM region using the NASA GEOS model in the context of recent NSF/NASA aircraft campaign, Asian Summer Monsoon Chemical & Climate Impact Project (ACCLIP), conducted in summer 2022 over the western N Pacific
- GEOS model set up:
  - Emission of CO, aerosols and their precursor gases: including anthropogenic, biomass burning, volcanic, biogenic, desert dust, and marine sources
  - Tagged source regions: separating anthropogenic CO emissions from South Asia and East Asia to assess their contributions to the sub-seasonal variability of UTLS composition

Fossil fuel + biofuel CO emission

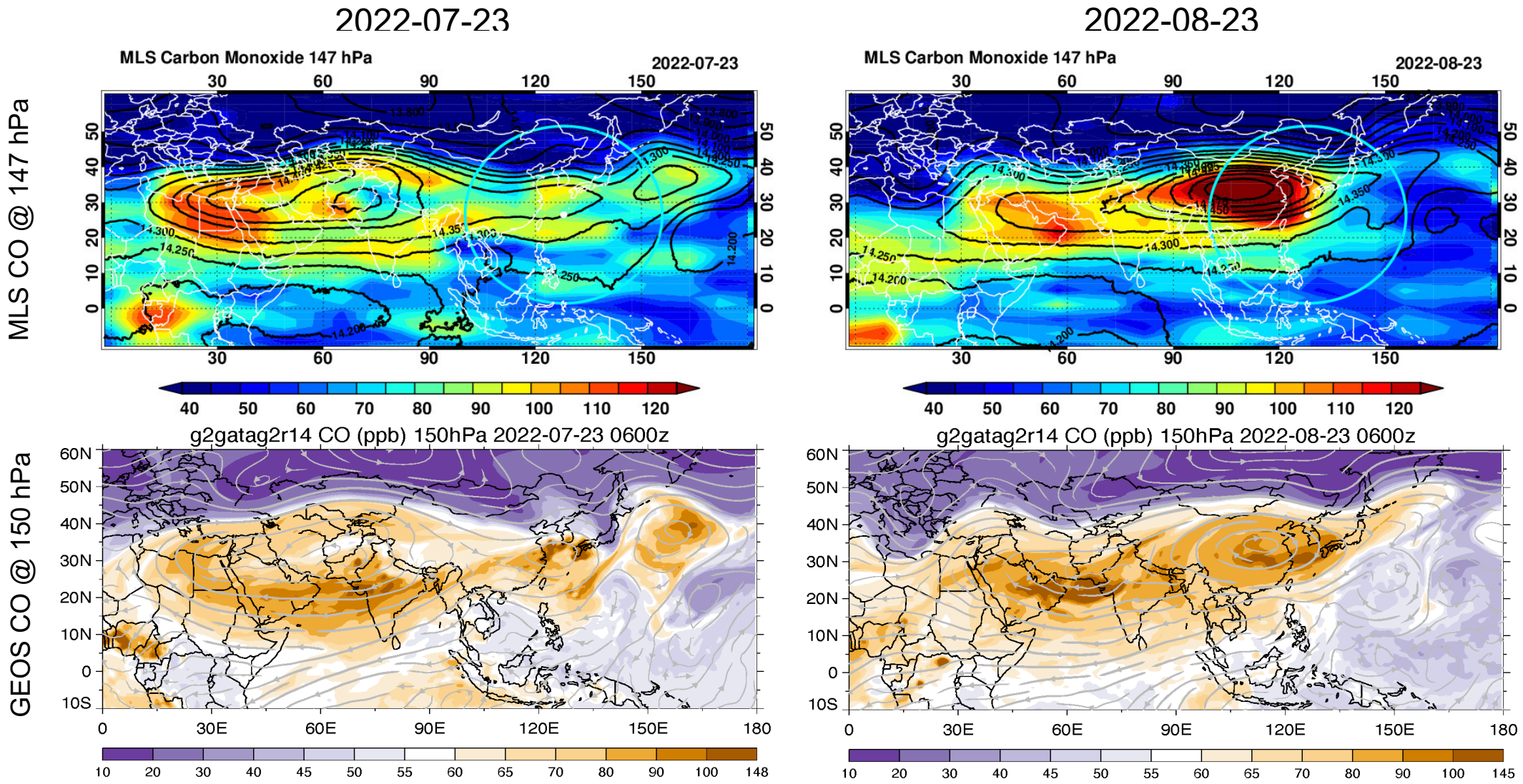



(Source: CEDS 2010 emission, Hoesly et al., 2018)

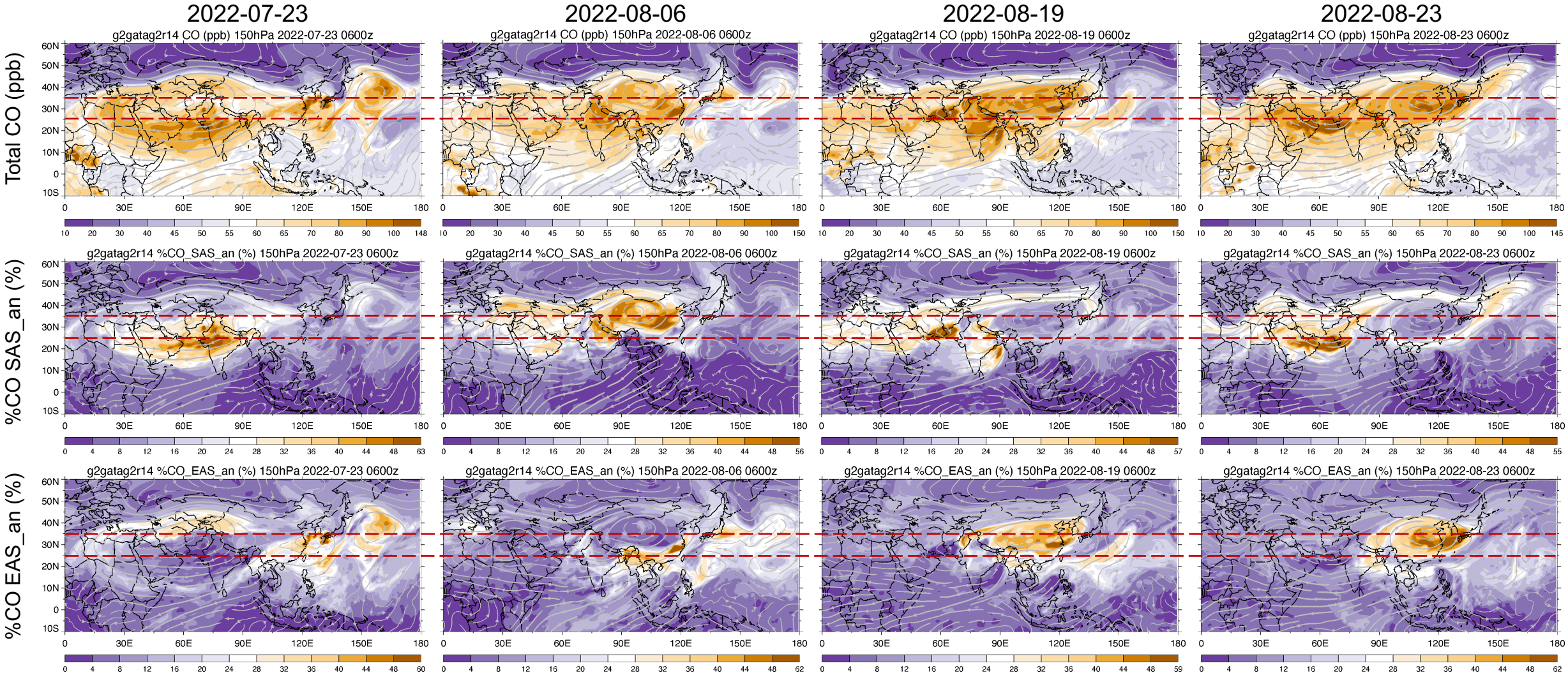
Tagged fossil fuel + biofuel CO regions



# CO at ~150 hPa from satellite retrieval by MLS and GEOS simulation: Examples of ASM anticyclone movements and eddy shedding



# Sub-seasonal variation of ASM anticyclone transport: CO at 150 hPa and source region attribution




SAS pollutants fill the ASMA core; EAS pollutants circle around the ASMA core

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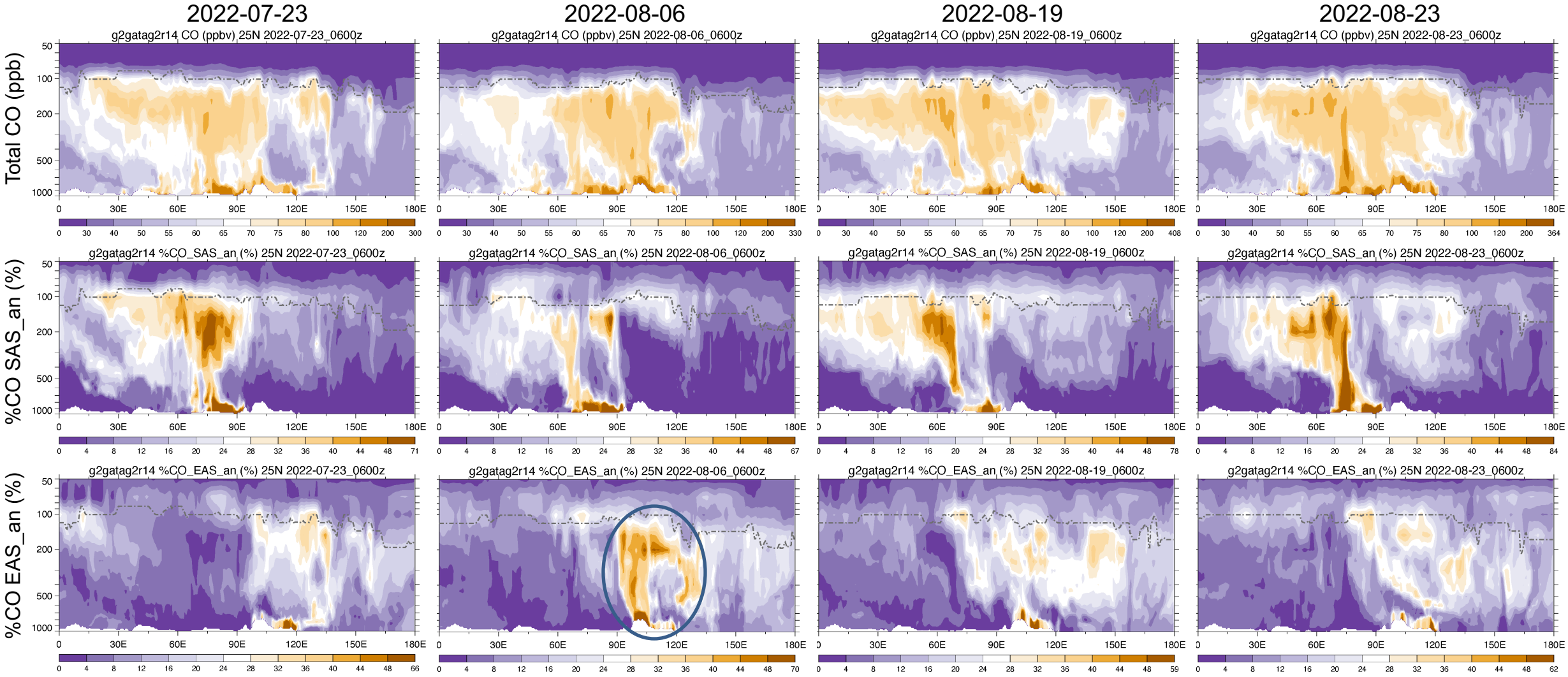
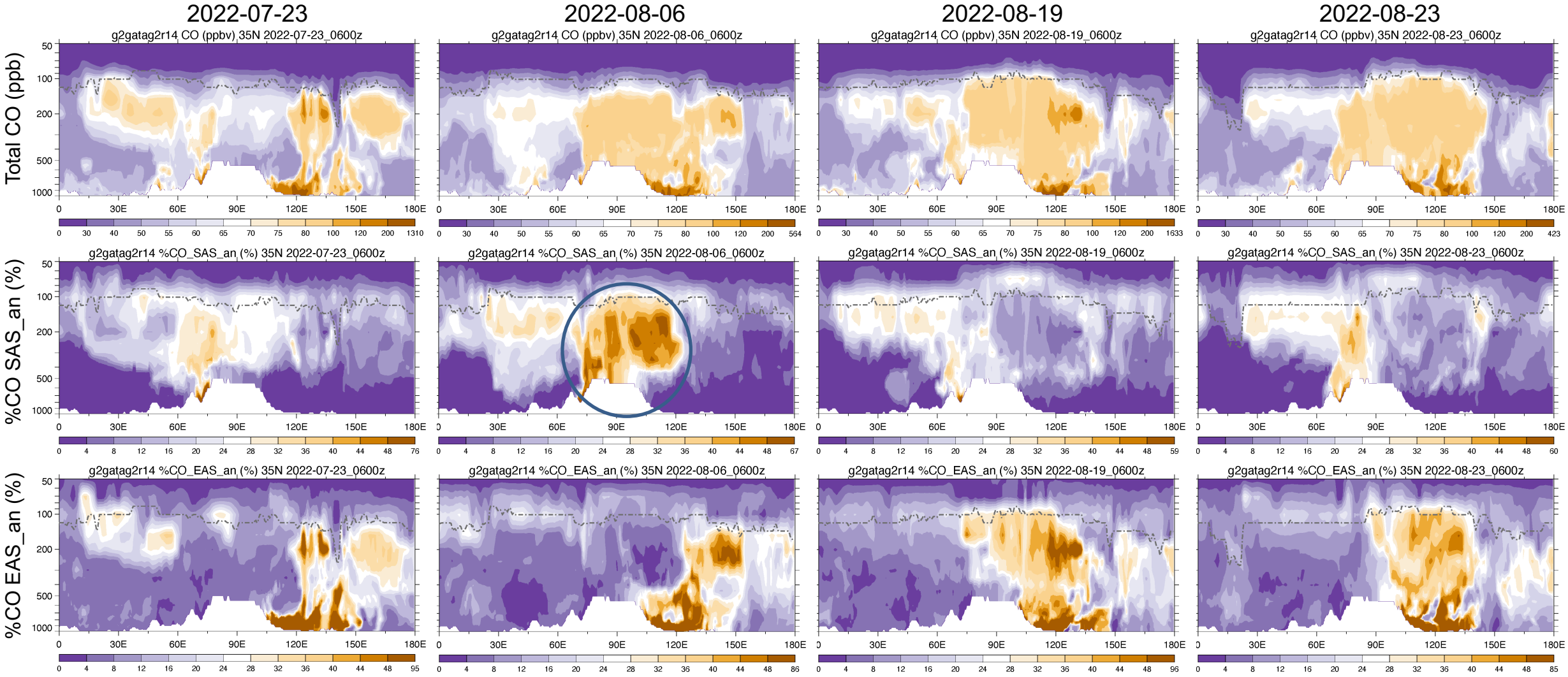
# Vertical transport patterns and source region attribution: longitude-pressure curtain at 25N




At 25N: The strongest convective transport of CO is generally over SAS (except 08-06) with prevailing feature of westward spreading in UTLS. Eastward shedding is mostly from the EAS airmass.

# Vertical transport patterns and source region attribution: longitude-pressure curtain at 35N




At 35N: The strongest convective transport of CO is generally over EAS (except 08-06), which moves eastward either in bulk from BL to UT or by shedding in UT. Westward shedding is mostly from the SAS airmass.

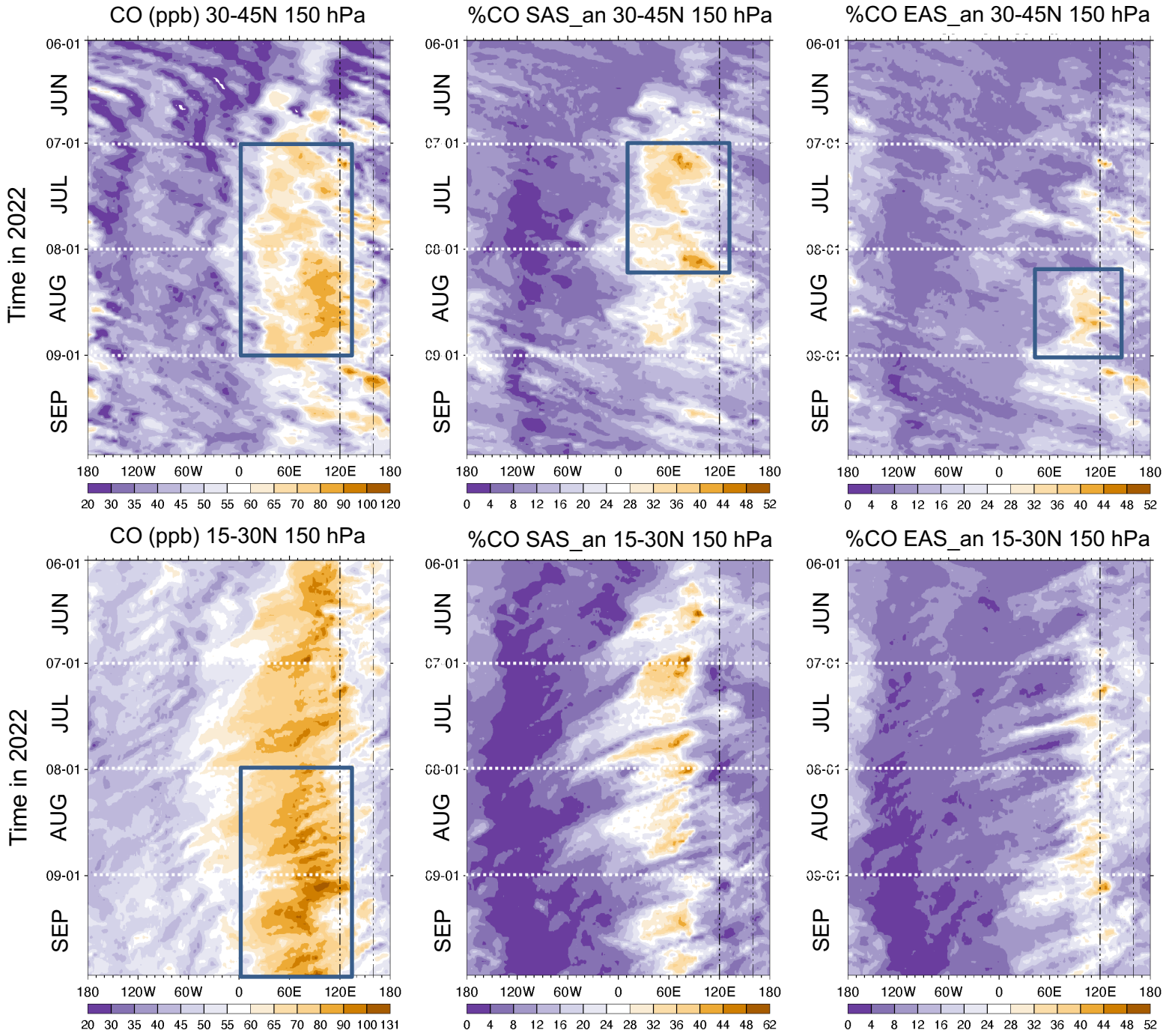
# Taking a broader look at sub-seasonal transport variability: CO at 150 hPa, June-Sept 2022

Northern part of ASMA region (30-45N):

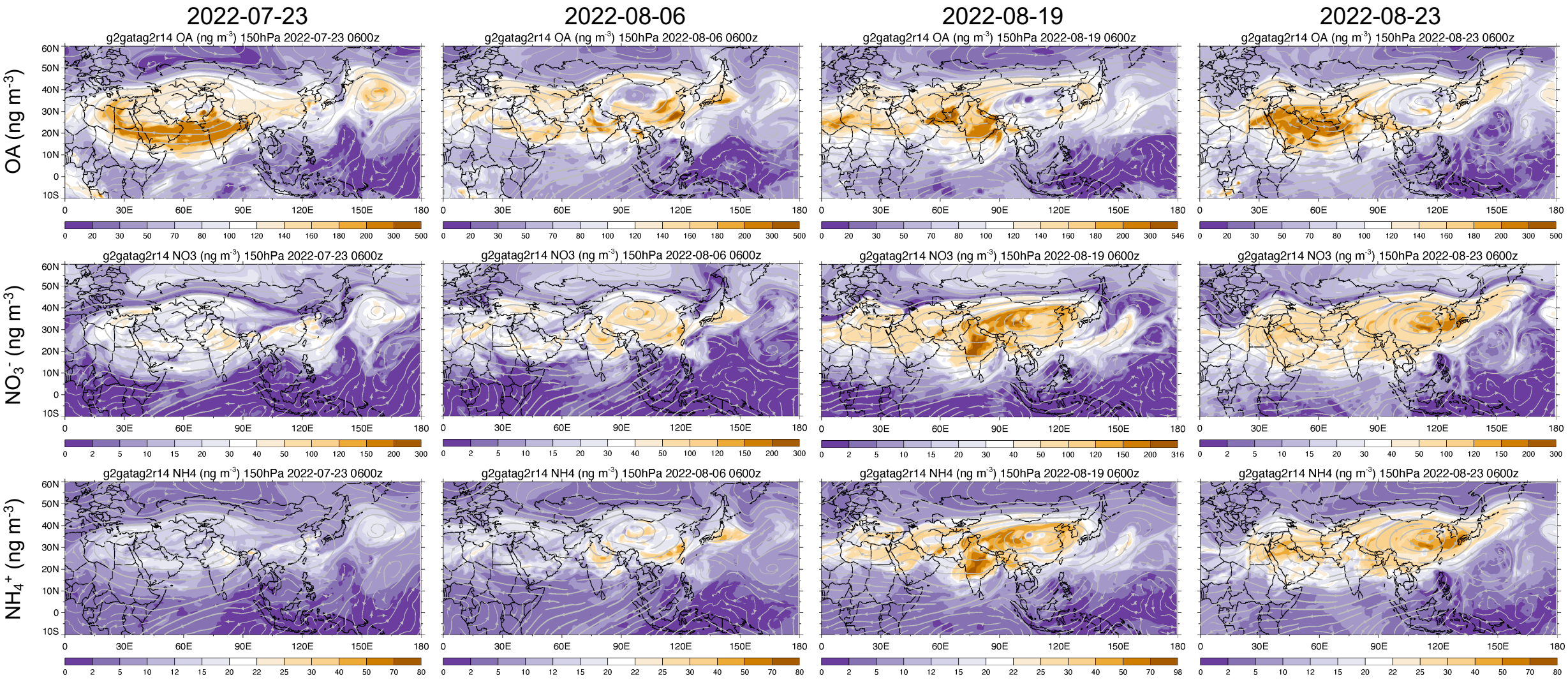
- Convective transport of CO is significantly stronger in July and August than in June and September
- Eastward shift of the core from July to August
- SAS anthro CO in ASMA is more important in July to early August but EAS anthro CO is more significant in the rest of August
- Eastward shedding occurring frequently (every few days)

Southern part of ASMA region (15-30N):

- Convective transport of CO is strong from June to September
- Sub-seasonal oscillation of the ASMA core evident in August and September
- Westward shedding of SAS CO reaching Africa even eastern Atlantic



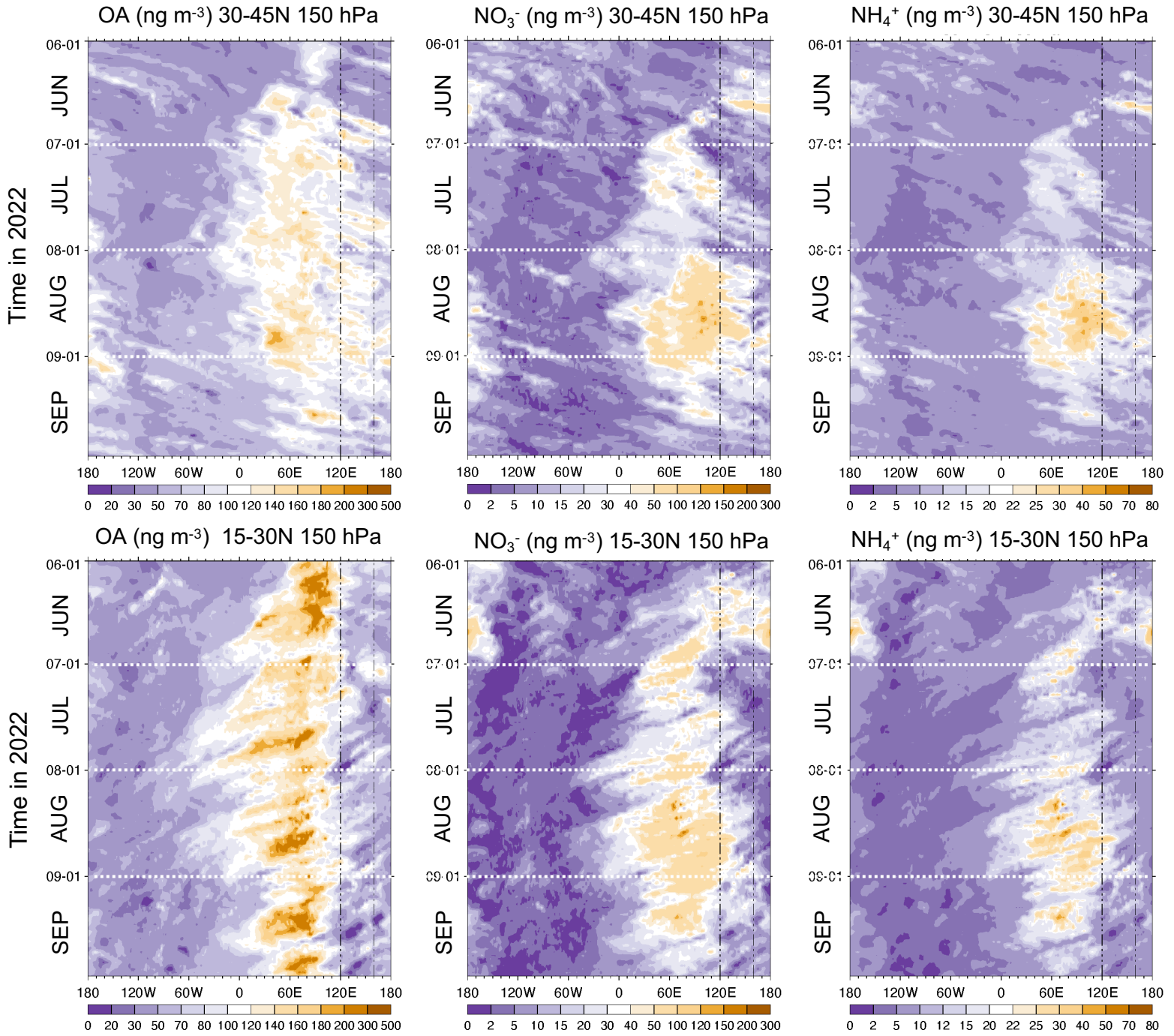
# Sub-seasonal variations of aerosol species at 150 hPa




Sub-seasonal variation patterns of OA is different from nitrate and ammonium

# Sub-seasonal variability of aerosol species at 150 hPa, June-Sept 2022

- Sub-seasonal variability of OA is more similar to that of CO in both latitudinal sections than nitrate and ammonium
- Both nitrate and ammonium show maximum concentrations in August in both latitudinal sections
- Because of chemical formation and dry/wet removals are involved for aerosols, their abundance in the UT have to be explained by those processes in addition to transport



# Conclusions

- Using the GEOS model simulations of CO and aerosol species, we have examined the sub-seasonal variabilities of ASM transport of surface-generated pollutants to the UTLS
- We have shown that there are substantial sub-seasonal variabilities of the ASM anticyclone core movements and associated shedding events
- With tagged regional emissions of anthropogenic CO, we have revealed the difference of pollutants' origins within the ASM anticyclone core that is the results of the variability of ASM
- One of the major implications of such ASM sub-seasonal variability has been demonstrated with the aerosol composition in the UTLS that changes with the airmass origins and transport pathways